

USE OF A SATELLITE PHOTOGRAPH TO CALCULATE AN INDIRECT MEASUREMENT OF PEAK DISCHARGE

Background

On October 17-18, 1998, a severe thunderstorm produced as much as 30 inches of rainfall resulting in unprecedented peak stages and discharges in the lower Guadalupe River in South Texas (Slade and Persky, 1999). The peak was about 3 feet higher than the previous maximum peak stage since flood records began in 1833. Slope-area indirect measurements of the peak discharges were needed (Dalrymple and Benson, 1984) to determine the peak discharges at the three U.S. Geological Survey streamflow-gaging stations in the reach.

A slope-area computation requires peak stages and cross-sectional properties at two or more sections along a reach. The data normally are documented by field surveys. However, the water surface was about 3 miles wide during the peak at the downstream-most station, and access permission to the properties to be surveyed would have been difficult to obtain. Even if permission could have been obtained, the field surveying would have required many weeks of work for several people. Therefore, an attempt was made to obtain an aerial photograph of the flood to reduce the time required to make the indirect discharge measurement.

Approach

A satellite photograph of the flood, taken a few days after the peak, was obtained for a reach about 3 miles upstream and 3 miles downstream from the streamflow-gaging station on the Guadalupe River at Victoria, Texas. The resolution for the image (1 meter) was sufficient to identify the edges of debris lines and disturbed vegetation along the banks. These edges represent remnants of the peak water surface. The remnants were located and used to create digitized vector arcs of the borders of the peak for both banks along the reach.

The low-flow channel meanders considerably throughout the area; its flowpath is longer than much of the floodplain flow, thus two-dimensional flow is abundant. A 13,500-foot reach within the 6-mile reach was selected for analysis of the indirect discharge measurement. The selected reach is believed to provide the best representation of one-dimensional flow in the area and thus best meets the criteria for a slope-area discharge computation.

The flood-border arcs were superimposed onto a same-scale image of the topography of the area (fig. 1). The flood borders on the topographic map then were used to identify the peak elevations of the water surface along the reach. The water-surface profile (plot of peak stage to river-channel stationing) was developed for the peak stages along the reach (fig. 2). The water-surface profile shows a 14-foot fall of peak stage along the reach. Five peak stages, field located and surveyed along the upper one-half of the reach on the left bank, were plotted on the profile. Each surveyed peak stage was within 1 foot of the profile, thus verifying its accuracy (fig. 2).

Two cross sections were delineated on the topographic image (fig. 1). The cross-sectional area and other required cross-sectional properties were determined for the peak stage at each cross section. The length of the reach traveled by the peak flow is needed for the computation. However, the flowpath in the floodplain is shorter than that in the low-flow channel. Only about 6 percent of the total conveyance was within the low-flow channel and about 94 percent was within the floodplain, thus the representative flowpath was calculated by giving 6 percent weight to the length of the low-flow channel and 94 percent weight to the length of flow in the floodplain. Flow in the floodplain was assumed to travel parallel to the borders of the peak.

Manning's roughness values were selected for the cross sections on the basis of field visits to the site and review of low-level aerial photographs of the area. The peak discharge was calculated as described by Dalrymple and Benson (1984).

Peak Discharge and Verification

The peak discharge is calculated as 466,000 cubic feet per second at the Victoria station for October 17-18, 1998. Conventional slope-area calculations require that at least three cross sections be processed, which would provide at least two independent values of peak discharge for verification. However, a highway and bridge near the middle of the reach and at the gaging station affected the shape of the peak water surface in that area (fig. 2). Inclusion of an additional cross section in this area would violate the criteria for slope-area computation. Locating an additional cross section away from the affected water surface would place it too close to one of the other two sections, which also would violate the criteria for slope-area computation. Therefore, only two sections were analyzed for the discharge measurement.

A slope-area indirect measurement for the October flood was made using conventional field surveying at nearby streamflow-gaging station Guadalupe River at Cuero, Texas. Because the drainage area for the watershed between this station and the Victoria station is only about 5 percent of the drainage area at the Victoria station, and the largest rainfall depths were upstream from both stations, the peak discharges for the two stations should be comparable. The peak discharge at the Cuero station is 473,000 cubic feet per second, which is within 2 percent of the peak discharge at the Victoria station. The indirect discharge measurement using the satellite image thus is verified by a nearby indirect discharge measurement using conventional procedures.

Criteria for Use of Satellite Photograph

Using satellite image or other aerial photographs to calculate a slope-area indirect measurement is beneficial because minimal field work is needed for the procedure and the measurement can be calculated in a fraction of the time required by the conventional procedures. However, specific criteria should be met to use the procedure, and peak stages should be measured in the field for at least a few sites to verify the peak-stage profile from the image.

The recommended criteria for using the procedure include:

1. The land surface as defined by the digital elevation model or topography map should represent the actual land surface at the time of the flood. A minimal effort to verify this could include a survey or measurement of the maximum depth in the channel to verify that fill or scour has not occurred in the deepest part of the channel.
2. The flood depths should be large enough in relation to the contour interval of the topography so that the cross sections will have sufficient definition.
3. The potential error in the water-surface profile should be a minimal fraction of the fall in the water-surface profile, because the fall in the water surface between the cross sections is directly proportional to the calculated discharge. Smaller contour intervals in the topography (or increased topographic resolution) allow for smaller potential errors in the water-surface profile. Also, there are potential errors in the border of the flood as identified from the aerial photograph. These errors are related to the resolution and scale of the photograph and the ability to identify flood-peak marks. Incorrect superposition of the flood border onto the topographic image also can contribute to the error in the flood-peak profile. Because this error is minimized for peaks on flat banks and maximized for peaks on steep banks, efforts should be made to identify and digitize peak marks on flatter ground.

References

Dalrymple, Tate and Benson, M.A., 1984, Measurement of peak discharge by the slope-area method: U.S. Geological Survey Techniques of Water Resources Investigations Book 3 Chap. A2, 12 p.

Slade, R.M., Jr., and Persky, Kristie, 1999, Floods in the Guadalupe and San Antonio River Basins in Texas, October 1998: U.S. Geological Survey Fact Sheet FS-147-99, 4 p.